# Drying Behaviour and Mathematical Modeling of Mistletoe (Viscum Album L.) in UV Combined Convective Drier

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**Abstract:** The thin layer drying behavior of *Viscum album* L. (mistletoe) leaves was investigated in UV combined convective drier. Drying air temperatures and velocities were selected as 60-70 and 80$^{O}$C, and 0.5-1 and 1.5m/s respectively. Drying curves obtained by using experimental data were fitted to the six models reported in the literature. Comparing the determination of coefficient (R), reduced chi- square ($\chi^2$) values of six models, it was obtained that the Modified Page model represents the best fitting.

## Introduction

Viscum album L. commonly known as mistletoe is a semi parasitic plant, which normally grows on a variety of trees. The major constituents of Viscum album L. are the lectins, which include viscumin, polypeptides known as viscotoxins and a number of phenolic compounds found in their free state or as glycosides(Al-Achi, 2005) and also typically include lignans, caffeic acid, vitamin C (Ergun&Deliorman,1996) Because of the rich chemical content, Viscum album L. has been used for the treatment of many diseases, both in traditional medicine and in complementary medicine. It was firstly used for the treatment of epilepsy and dermatitis in Europe (Tenorio et al.,2005). A number of biological effects, such as anticancerand, antimycobacterial, antiviral have been reported.

Drying can be described as an industrial preservation method in which water content and activity of fruits and vegetables are decreased by heated air to minimize biochemical, chemical and microbiological deterioration (Doymaz and Pala, 2003). Drying provides not only a longer shelf-life to the food but also results in light weight transportation and comparatively smaller storage space (Sharma et al, 2005).

Nowadays some new techniques intending to shorten the drying time and improve the final quality of the dried products such as microwave, IR and UV assisted drying have begun to use. UV drying is an especially used in field of printing and packaging industry where fast drying. UV drying is also used in carton including medicine and food labeling, plastic material, the wood finishing industry and metal decorating (http://www.noblelight.net/products/ultraviolet_curing/curing.asp).(http://www.wluv.de/uv-trocknung.html?&L=1). Viscum album L. extracts is used for the treatment of many diseases as mentioned above. In many treatments, in order to increase the extraction yield, materials which will be extracted are first dried and then grinded to be expanded the surface area. In order to get easier the grinding process and longer the storage period, drying is selected as preservation methods of Viscum Album L. leaves. Although numerous thin layer drying models have been published in the literature describing the drying behavior of leaves during convective drying such as parsley (Soysal, 2004), spinach (Karaaslan&Tuncer,2008), rosemary leaves (Aslan & Özcan, 2008), mint leaves (Özbek & Dadali, 2007), mate leaves (Zanoelo,2007). There is no information concerning the drying of Viscum album L. and UV assisted dying of foodstuffs. The aim of this study was; to determine the drying characteristics of Viscum album L. leaves in UV assisted convective drier and to obtain the most suitable mathematical model defined the drying.

## Material and Methods

Sample preparation and drying equipment

Viscum Album L. plants collected from pear trees and provided from Giresun, Turkey in March, 2008 were used in drying experiments. Leaves of plants were diminished from handle, washed and dried on a filter paper to eliminate the surface water. After then leaves are placed into plastic bags and stored at +4$^o$ C until drying. The initial moisture content of Viscum Album L. sample was 70% (wet basis, wb).

The UV combined convective dryer consists of a fan, fan speed controller, air heater, heat power controller, thermometers, and stainless-steel mesh sieve and three UV lamps (Philips) were located onto sieve with the distance of 15cm. Air velocity was measured by an anemometer (LCA 6000, Lufttechnik GmbH, England). The schematic diagram of the dryer is shown in Figure 1.

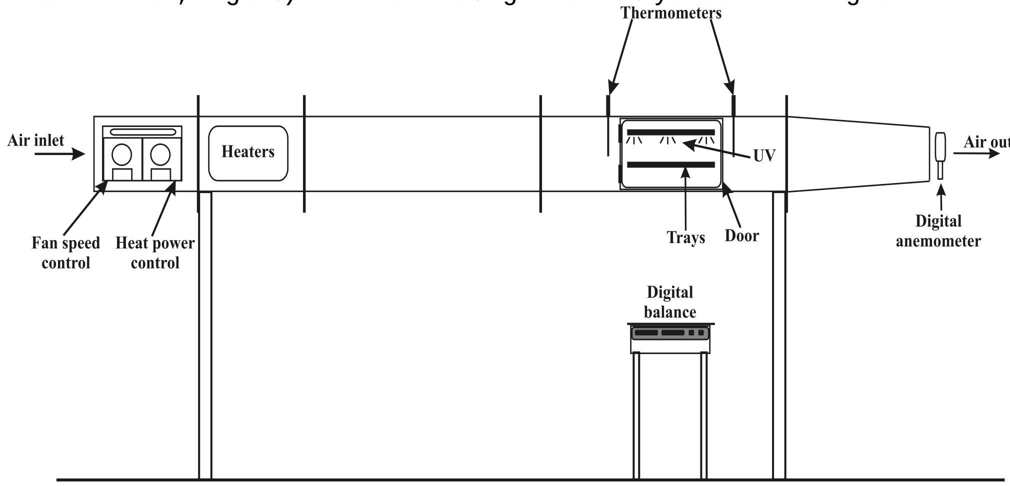


Figure 1: Schematic diagram of experimental drier

## Drying procedure

Drying experiments were carried out at temperatures of 60, 70 and 80°C, velocities of 0.5, 1 and 1.5 m/s in horizontal-flow. UV lamps, air heaters and fan adjusted to required flow rate had been operated to obtain the steady state conditions before drying experiments have been started. Samples of about 15 g were used for drying experiments. Dimensions of tray were 21x18 cm. The weighing tray with the sample was placed in the dryer. In all experiments, samples were placed as a thin layer. The samples were weighed at various time intervals, ranging from 5 min at the beginning to 30 min during the last stage of the drying process. A digital electronic balance with accuracy of 0.01 g (Precisa, BJ610C) was used to measure the weight of the samples. The drying process was continued until the material achieves its final moisture content at which the moisture content does not decrease significantly. Final moisture content was taken as the equilibrium moisture content. Each test was replicated three times and the average values were used to construct the drying curves. Dryer walls were insulated with polystyrene.

## Mathematical modeling

For mathematical modeling, the six commonly used thin layer drying models shown in Table 1 were tested to select the best model for describing the drying behavior of Viscum album L. leaves during UV assisted convective drying process. The regression analysis was performed using Statistica Computer Program. The goodness of fit of each model was evaluated using the correlation coefficient (R) and the reduced chi-square ($\chi^2$). The higher the values of R and the lower the values of $\chi^2$, the better is the goodness of the fit (Akpinar, 2005; Midilli et al. 2002). $\chi^2$ can be calculated as follows:

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,i})^2}{N-z}$$

| Models | Equations | References |
|---|---|---|
| Newton | MR=exp(-kt) | Mujumdar(1987) Erentürk et al. (2004) |
| Page | $MR=exp(-kt^n)$ | Diamante and Munro (1993) ,Akpınar (2006) |
| Modified Page | $MR = exp[-(kt)^n]$ | Yaldiz and Ertekin (2001) |
| Henderson & Pabis | MR=a exp(-kt) | Henderson and Pabis (1961) |
| Logarithmic | MR=a exp(-kt)+c | Yağcıoğlu *et al.* (1999) |
| Midilli *et al.* | $MR=aexp(-kt^n)+bt$ | Midilli *et al.* (2002) |

Table 1 : Thin layer drying curve models

## Results and Discussion

Effects of air temperature

The variations of dimensionless moisture ratio with drying time at temperatures of 60, 70 and 80°C at 0.5 m/s was given in Fig. 2. An increase in air temperature resulted in a decrease in the drying time. The required drying times to reach equilibrium moisture content from the initial moisture content at 0.5m/s for the selected drying air temperatures of the Viscum album L. leaves were found to be as 400, 280 and 180 min . As it would be expected, similar drying curves except for slopes were obtained for the 1 m/s and 1.5 m/s drying conditions. The times required reaching equilibrium moisture content for 1 m/s were obtained as 360, 200 and 160 min for the selected temperatures. The drying times for air velocity of 1.5 m/s at air temperatures of 60, 70 and 80°C were obtained as 360, 200, 160 min. It could be concluded that from the Figure 2; drying air temperature has an important effect for the drying of Viscum album L. leaves.

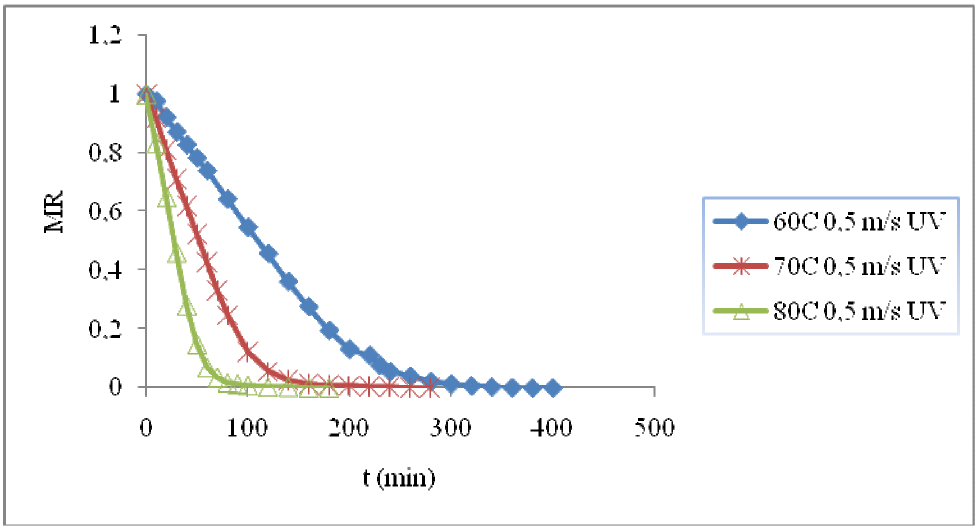


Figure 2: Drying curves for Viscum album L. at various air temperatures

Effects of air velocity

In order to investigate the effect of air velocity on drying of Viscum album L. leaves, air velocity values were selected as 0.5, 1 and 1.5 m/s. Due to the similarity of the drying curves, the effects of different drying air velocity were drawn for only 60° C. The effects of drying air velocities at air temperature of 60° C were shown in Figure 3. As it can be seen from the figure , with an increase in air velocity causes a small increase in the drying rate. When the drying air velocity was increased from the 0.5 m/s to 1 m/s drying rate was also increased. However drying rates are almost similar at 1 m/s and 1.5 m/s velocities.

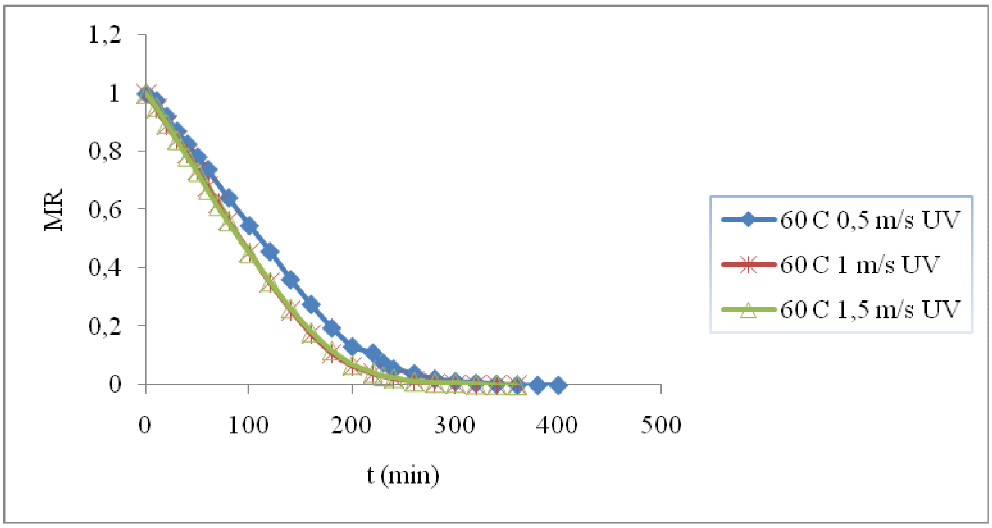


Figure 3: Drying curves for Viscum album L. at various air velocities

Modeling

The results of the statistical analysis were in Table 2. Among the considered mathematical drying models, the Modified Page model was found to be more suitable for predicting the drying behavior of Viscum album L., with the values for R above 0.99 and with the lowest value of $\chi^2$. In order to take into account for the effect of the drying variables on the Modified Page model a multiple regression analysis was performed on the drying variables in terms of drying air temperature (T, °C); and air velocity (V, m/s) since they affected the drying coefficients k and n of the Modified Page model. The multiple combinations of the different parameters that gave the highest R value were included in the final model.

Arrhenius type modeling was one of the best methods to describe the drying rate k and drying parameter n of the Modified Page model, related details and values for these coefficients were given below:

$$k = 3.185 * V^{0.452} * \exp(-349.69/T)$$

$$n = 1.495 * V^{0.049} * \exp(0.589/T)$$

These models can be used to estimate the moisture content of the Viscum album L. at any time during the UV asisted drying process with an acceptable accuracy. Validation of the selected model was made by comparing the computed moisture contents with measured values in all drying runs. The performance analysis of the models at different velocities and temperatures of drying air was illustrated in Figure 4. As can be observed in this figure, consistency of fitting the drying data into this model is very good for all of the experimental drying air conditions. Thus, this model may be assumed to represent the drying behavior of Viscum album L. for UV assisted drying.

| Model | T (°C) | V (m/s) | R | $\chi^2$ |
|---|---|---|---|---|
| Newton | 60 | 0.5 | 0.9933 | 0.00793 |
| | | 1 | 0.9905 | 0.005954 |
| | | 1.5 | 0.9849 | 0.009083 |
| | 70 | 0.5 | 0.9917 | 0.004039 |
| | | 1 | 0.9906 | 0.004377 |
| | | 1.5 | 0.9925 | 0.003069 |
| | 80 | 0.5 | 0.9892 | 0.004069 |
| | | 1 | 0.9898 | 0.003179 |
| | | 1.5 | 0.9936 | 0.00165 |
| Page | 60 | 0.5 | 0.9989 | 0.001719 |
| | | 1 | 0.9939 | 0.002731 |
| | | 1.5 | 0.9707 | 0.016193 |
| | 70 | 0.5 | 0.998 | 0.001573 |
| | | 1 | 0.9994 | 0.00023 |
| | | 1.5 | 0.9985 | 0.000438 |
| | 80 | 0.5 | 0.9922 | 0.004608 |
| | | 1 | 0.9993 | 0.000194 |
| | | 1.5 | 0.9994 | 0.000311 |
| Modified Page | **60** | **0.5** | **0.999** | **0.001518** |
| | | **1** | **0.998** | **0.000604** |
| | | **1.5** | **0.989** | **0.005669** |
| | **70** | **0.5** | **0.9991** | **0.000265** |
| | | **1** | **0.9993** | **0.000249** |
| | | **1.5** | **0.9987** | **0.000665** |
| | **80** | **0.5** | **0.9994** | **0.000148** |
| | | **1** | **0.9996** | **0.000105** |
| | | **1.5** | **0.9999** | **0.000065** |
| Henderson & Pabis | 60 | 0.5 | 0.9914 | 0.005771 |
| | | 1 | 0.9868 | 0.004145 |
| | | 1.5 | 0.9791 | 0.007519 |
| | 70 | 0.5 | 0.9895 | 0.002967 |
| | | 1 | 0.9899 | 0.003371 |
| | | 1.5 | 0.9927 | 0.002648 |
| | 80 | 0.5 | 0.9882 | 0.00329 |
| | | 1 | 0.9892 | 0.00271 |
| | | 1.5 | 0.9933 | 0.001467 |
| Logarithmic | 60 | 0.5 | 0.9936 | 0.001956 |
| | | 1 | 0.9926 | 0.003791 |
| | | 1.5 | 0.9893 | 0.011565 |
| | 70 | 0.5 | 0.9923 | 0.002121 |
| | | 1 | 0.9794 | 0.018244 |
| | | 1.5 | 0.992 | 0.002336 |
| | 80 | 0.5 | 0.9893 | 0.002835 |
| | | 1 | 0.9899 | 0.002383 |
| | | 1.5 | 0.9936 | 0.001426 |
| Midilli *et al.* | 60 | 0.5 | 0.9975 | 0.001692 |
| | | 1 | 0.9963 | 0.002405 |
| | | 1.5 | 0.9755 | 0.016067 |
| | 70 | 0.5 | 0.9961 | 0.002354 |
| | | 1 | 0.5559 | 0.156692 |
| | | 1.5 | 0.9987 | 0.00043 |
| | 80 | 0.5 | 0.9897 | 0.005692 |
| | | 1 | 0.9994 | 0.00016 |
| | | 1.5 | 0.9989 | 0.000547 |

Table2: The results of the statistical analysis

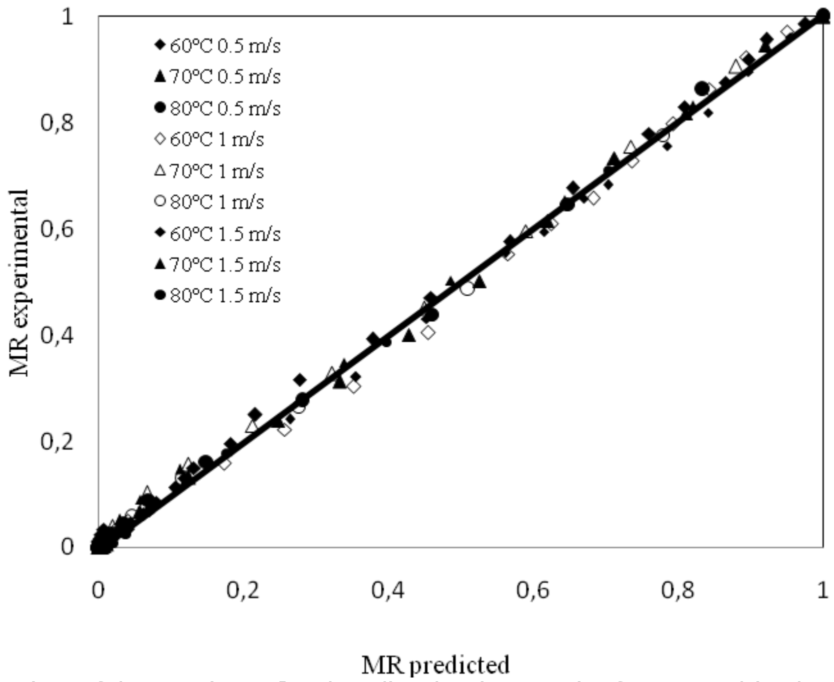


Figure 4. Comparison of the experimental and predicted moisture ratios for UV-combined convective drying.

## Conclusion

In this study, drying behavior of Viscum album L. in UV combined convective drier was investigated. Drying air temperature has the most important effect for the drying of the Viscum album L. Drying air velocity has a little effect on drying. Drying rate is different only at 0.5 m/s but at 1 and 1.5 m/s drying rates are similar. Within the six thin-layer drying correlations considered, the Modified Page model provided the best representation of the Viscum album L. drying kinetics for the UV combined convective drier.

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## References


Al-Achi, A. (2005). Mistletoe (Viscum album L.). *U.S. Pharmacist*, 30, 12-18.

Arslan, D., Özcan, M.M. (2008). Evaluation of drying methods with respect to drying kinetics, mineral content and colour characteristics of rosemary leaves, *Energy Conversion and Management*, 49(5), 1258-1264.

Akpinar, E.K. (2006). Mathematical modelling of thin layer drying process under open sun of some aromatic plants. *Journal of Food Engineering*, 77(4), 864-870.

Akpinar, E. K. (2005). Determination of suitable thin layer drying curve model for some vegetables and fruits. *Journal of Food Engineering*, 73(1), 75–84.

Diamante, L.M., Munro, P.A. (1993). Mathematical modeling of thin layer solar drying of sweet potato slices. *Solar Energy*, 51(4), 271–276.

Doymaz,I.,& Pala, M. (2003). The thin-layer drying characteristics of corn. *Journal of Food Engineering*, 60, 2, 125-130.

Erenturk, S., Gulaboglu, M.S., Gultekin, S. (2004). The Thin-layer drying characteristics of rosehip, *Biosystems Engineering* 89(2), 159–166.

Ergun, F., Deliorman, D. (1996). HPLC analysis of ascorbic acid in Viscum album L. samples. *J .Fac. Pharm. Gazi*, 13(2) 121-126.

Henderson, S.M., Pabis, S. (1961). Grain drying theory I: temperature effect on drying coefficient. *J Agric Res Eng*, 6:169–74.

Karaaslan, S.N., Tunçer, İ.K. (2008). Development of a drying model for combined microwave–fan-assisted convection drying of spinach. *Biosystems Engineering*, 100(1), 44-52.

Midilli, A., Kucuk, H., Yapar, Z. (2002). A new model for single layer drying. *Drying Technology*, 20(7), 1503–1513.

Mujumdar, A.S. (1987). Handbook of industrial drying. Marcel Dekker, New York.

Özbek, B., Dadali, G., (2007). Thin-layer drying characteristics and modelling of mint leaves undergoing microwave treatment. *Journal of Food Engineering*, 83(4), 541-549.

Sharma, G.P., Verma, R.C., & Pathare, P. (2005). Mathematical modeling of infrared radiation thin layer drying of onion slices. *Journal of Food Engineering*, 71(3), 282–286.

Soysal, Y. (2004). Microwave drying characteristics of parsley. *Biosystems Engineering*, 89(2), 167–173.

Tenorio, F.A., del Valle, L., Gonzalez, A., & Pastelin, G., (2005). Vasodilator activity of the aqueous extract of Viscum album. *Fitoterapia*, 76(2), 204-209.

Yağcıoğlu, A. (1999). Tarım ürünleri kurutma tekniği. Ege Üniversitesi Ziraat Fakültesi Yayınları, No:536. İzmir.

Yaldız, O., Ertekin, C. (2001). Thin layer solar drying some vegetables. *Drying Technology*, 19(3-4), 583–596.

Zanoelo, E.F., di Celso, G.M., Kaskantzis, G. (2007). Drying Kinetics of Mate Leaves in a Packed Bed Dryer. *Biosystems Engineering*, 96(4), 487-494.

http://www.noblelight.net/products/ultraviolet_curing/curing.asp

http://www.wluv.de/uv-trocknung.html?&L=1